Scattering Of Baroclinic Long Waves By Complex Coastal Topography: An Application Of An Isopycnal Model

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Award # N00014-00-1-0093

LONG-TERM GOALS

The long-range objective of this work is to understand the role of complex bathymetry, non-linearity and boundary layers on the dynamics of flow in the coastal ocean.

OBJECTIVES

The objective of this work is to examine long period processes on the continental slope using an isopycnal numerical model and the California Bight as a case study. The model is used to study the response to complex bathymetry of remotely forced baroclinic disturbances with periods of 20 to 30 days. A series of idealized model runs are performed to investigate progressively more complex bathymetry and coastline geometry, using a detailed existing set of observations from the southern California Bight for model initialization and evaluation. The work provides a robust test of a new model for the coastal ocean. In addition, the sources of the disturbances in this frequency band are being explored.

APPROACH

Many coastal modeling studies in the last three decades have carefully avoided regions of complex topography. This can be done with some success when studying processes over the shelves. However, the continental slope is indented by submarine canyons, offshore ridges, and banks.

In the southern California Bight energetic long period (20-30 d) fluctuations dominate the variances in the coastal flow field over the continental slope. Coastal sea level data south of this region are consistent with propagation speeds of a first mode CTW (coastal trapped wave). Current meter data suggest that these disturbances enter the coastal basins within the Bight from the southeast and appear to pivot counterclockwise around the basin, so that some portion of the energy exits the basin over the western sill, whereas the remainder passes into the Santa Barbara Channel. The phase speed of the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Scattering Of Baroclinic Long Waves By Complex Coastal Topography: An Application Of An Isopycnal Model**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **School of Oceanography,,Box 357940, University of Washington,,Seattle,,WA, 98195**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-range objective of this work is to understand the role of complex bathymetry, non-linearity and boundary layers on the dynamics of flow in the coastal ocean.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

disturbances is reduced by an order of magnitude as the waves propagate around the basin. One of the issues to be examined in this work is how the disturbances transit through the topographically complex California Bight--do they pass through the Santa Barbara Channel or do they bypass it by turning offshore south of the channel (or does some portion of the energy go in each direction)?

Model studies suggest that scattering of CTWs by irregularities in the topography such as abrupt widening or narrowing of the shelf, or the existence of submarine canyons can cause dramatic alterations in the structure of coastal circulation patterns. In most situations, the energy of an incoming single mode wave is scattered into several higher modes, so that the spatial and temporal structure of the current field is significantly altered by the interaction with the topography. We address here the problem of disturbances propagating freely along the slope as they encounter a strong topographic change, in this case, an abrupt widening. Along the US west coast sharp widenings occur frequently over the continental slope; for example, near Point Conception, Cape, Mendocino and the Strait of Juan de Fuca. The model is tested in the southern California Bight, where the continental shelf has an abrupt change in orientation as it encounters the Santa Barbara Channel, in an area for which an extensive data set exists. The data are sufficient to provide initial conditions such as stratification and sea level fluctuations as well as to allow model evaluation.

We have taken two approaches in the study, first we examine the sources of the disturbances in the 20 to 30 day period band; second we explore how disturbances navigate the complex bathymetry at the California Bight. This particular problem, while relevant to important processes on continental slopes, will also allow testing of the isopycnal numerical model in a coastal oceanographic setting.

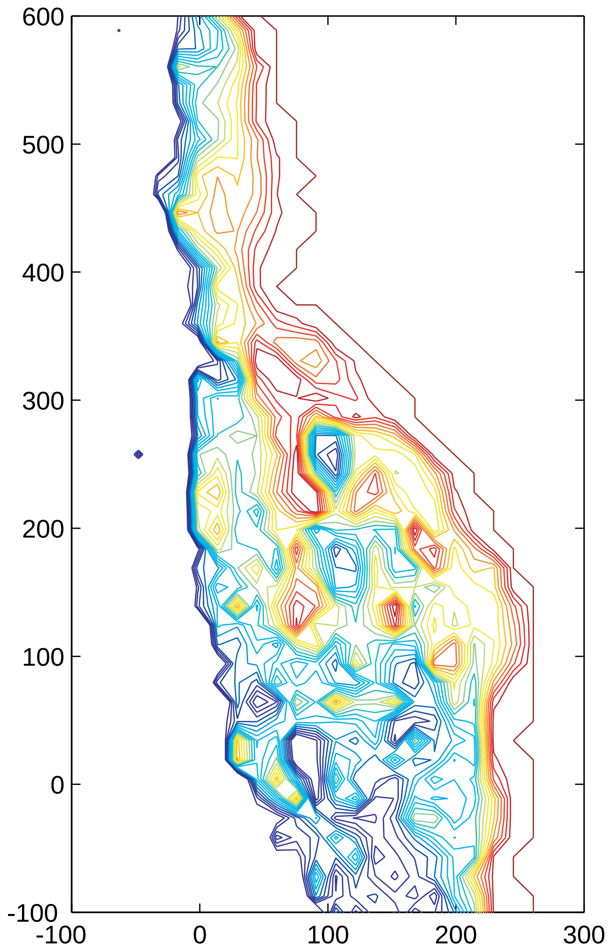
WORK COMPLETED

Origin of the disturbances. The long period, poleward propagating disturbances being modeled in this project are responsible for a majority of the velocity and temperature variance in coastal regions of the southern California Bight. Our model studies (see modeling Section) to date demonstrate that some energy passes through the Bight, where it might then propagate along much of the US west coast as an important source of variance in coastal currents.

The disturbances have several characteristics in common with so called "Tropical Instability Waves" (TIWs); in particular, period (20-30 d), seasonal cycle (maximum variance in fall and winter) and a subsurface maximum in variance (~100-200 m). The energy of these waves travels eastward and poleward across the Pacific as Rossby/gravity waves, impinging on the North American coast somewhere south of about 20 N. Sea level records examined to date suggest that the origin of the disturbances is at least several hundred kilometers south of the Bight. To explore possible connections between tropical instability waves and the coastal disturbances, dynamic height time series from the Equatorial Pacific TAO array were compared to coastal sea level data along North America during 1988, the year when our prior coastal analysis was performed. Time series have the same frequency content and seasonal cycle (Fig. 1 of 1999 annual report). Because the possibility of a direct connection between equatorial and coastal processes is highly relevant for model studies of the Pacific Ocean, we continue to explore this connection by expanding our data to 5 years (1986-1990), the period when we have comprehensive current data within the southern California Bight.

A paper has been submitted that provides new information on the spatial structure, propagation characteristics and structure of long period fluctuations being investigated with the model studies (Hickey, 2001).

Model results. In the last year, we have performed idealized model runs to evaluate what role the Santa Barbara Channel and Point Conception play in the propagation of energy up the California Coast. To do this, we constructed a set of idealized bathymetries and evaluated the changes in energy propagation by the inclusion of a slope, a significant bend

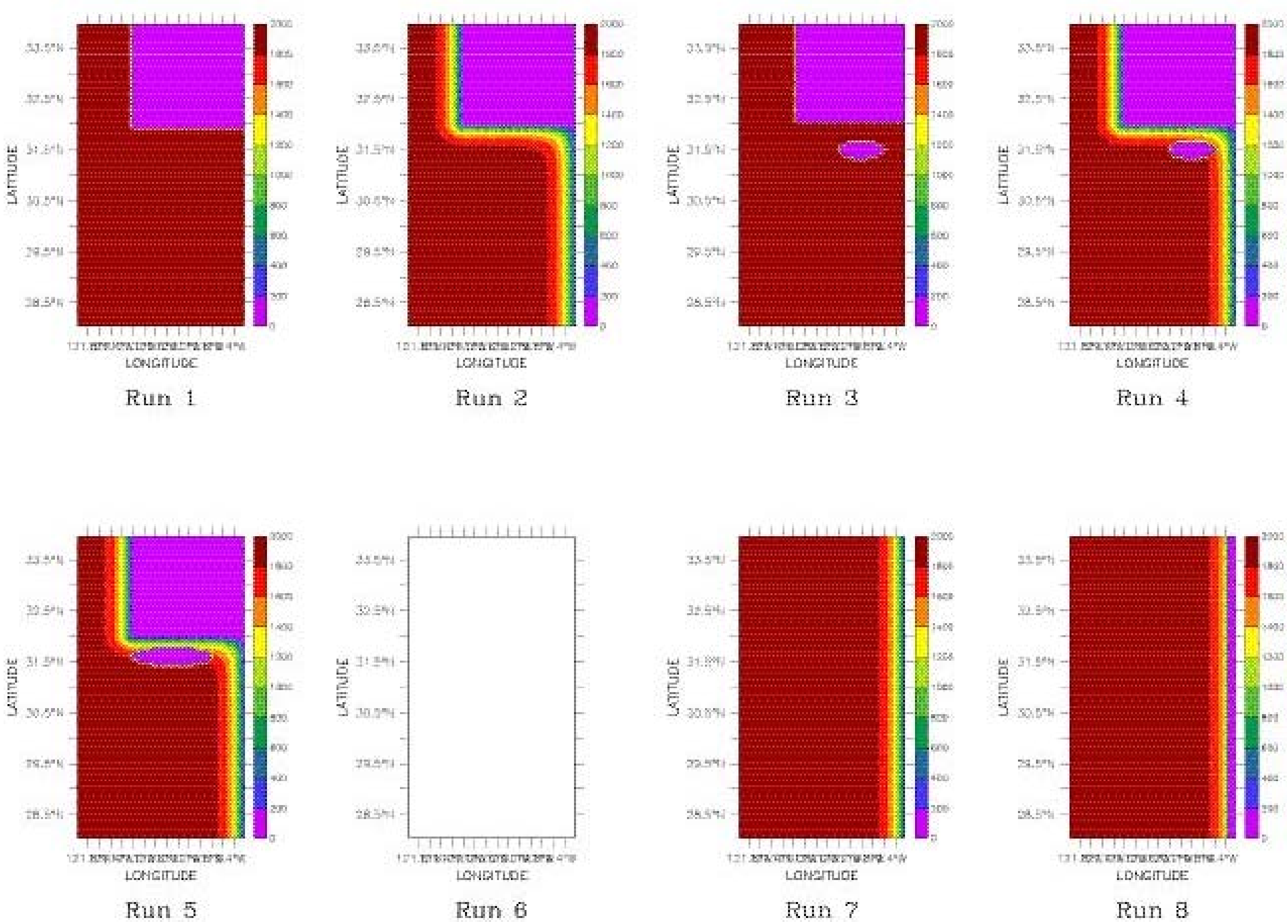


1. Bathymetry off the coast of California rotated so that the coast is in the y axis direction. Only depths less than 2000m are shown. Notice the complex bathymetry with the two most striking features being the bend in the coast from south of the Santa Barbara Channel to Point Conception and the Channel Islands. Axes distances are in km.

in the coastline, and islands. The topography is very complicated in the region. To simplify the model, we rotate the topography so that the coast lines up in a roughly North-South Direction (Figure 1).

Using Figure 1 as a guide, we formed a set of eight different bathymetries (Figure 2) and force a disturbance with a first coastally trapped wave mode shape. The model was run with 3 km resolution and spans a domain 600 by 800km. There are 8 isopycnal layers in the model simulation. The boundary conditions are closed, but the since it is only run for 15 to 20 days, the disturbance does not have enough time to make it back to the southern boundary. The model is sampled every 0.5 days.

As a diagnostic, the maximum energy (Figure 3) and the time that it takes from the beginning of the simulation to reach that energy maximum is calculated. This provides a way to calculate propagation speed and energy loss. The runs with a continental slope included show more energy loss than those with only a coastal wall. This indicates that frictional effects may be important as well as waves scattering. Likewise, the presence of islands near the coast does cause a small, but significant

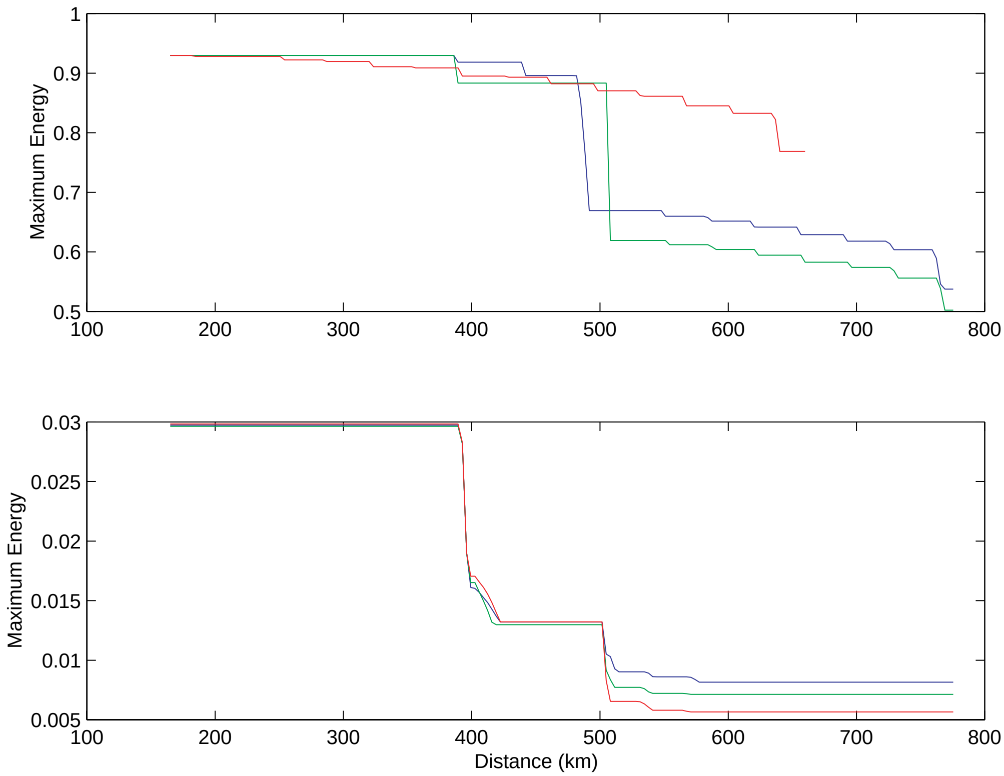


2. Bathymetry for the 8 different idealized runs. Runs 1, 3 and 6 all have flat bottom. While the other runs have a continental slope. Runs 1 through 5 all have the bend in the coast, while runs , 4 and 5 all have islands included. The maximum depth of the basin is 2000 m.

energy loss. The bend in the coast also generates energy loss, as the CTW is scattering into higher modes.   While the bend in the coast does not cause slowing of the disturbance, the islands do as some portion of the waves must pass around the island.

RESULTS

Our results to date include the following: 1) compelling evidence for a connection between the 20-30 day disturbances in the California Bight to TIWs has been compiled, 2) we have shown that the observed slowing of disturbances as they pass through the Bight can be explained by the dynamics of a



3. Maximum energy as a function of along shore distance. In the upper panel is shown Run 1 (blue) Run 3 (green) and Run 6 (red). Notice that the Run 6 has the most energy propagation, while Run 1 has less when it encounters the bend in the coast, while Run 3 has the least with both bend and island included. Lower panels shows Run 2 (blue) Run 4 (green) and Run 4 (red). The extent of the island also influences energy propagation as can be seen by the smaller energy in Run 4. Run 7 and 8 also show less energy loss, with Run 8 (with a small shelf) showing much greater energy transmission than runs with a slope only.

CTW interacting with the complex topography and have quantified the energy loss associated with their encounters with bathymetry, and 3) we have shown that a significant amount of energy is able to pass Point conception, contrary to some previous ideas about energy propagation. In the next year, a paper will be submitted for publication on this work.

IMPACTS/APPLICATIONS

The impact of our results is to improve coastal ocean simulations by demonstrating the importance of the inclusion of remote forcing. In addition, the successful demonstration of application of the isopycnal model to a coastal problem will encourage its use for other applications.

PUBLICATIONS

Hickey, B. A. 2001 Local And Remote Forcing Of Currents And Temperature In The Central Southern California Bight, submitted *Journal of Geophysical Research*.